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THE BREEDING HABITS OF THE EEL.

BY A. S. PACKARD, JR.

THERE is a considerable degree of mystery regarding the spawning time of the common eel (*Anguilla bostoniensis*), the place of spawning, and especially the differences between the male and female. The following facts appear to throw some light on the subject, and are published with the hope that it may stimulate others to observe with care and in detail all the facts regarding the spawning habits of a fish which is interesting as being the lowest bony fish, and is more and more used as an article of food, several eel-fishing establishments having been lately started in this country.

So far as we are aware, the eggs of the American eel were first discovered by Mr. John Mooney, of Providence, R. I., in October, 1877. Mr. Mooney is an intelligent mechanic and a close observer, but entirely self-taught. He carried the eggs to Prof. John Pierce, of Providence, who assures me they were veritable eggs, and measured one-hundredth of an inch in diameter.

Late in December, 1877, Mr. Vinal Edwards sent eight eels to the Museum at Cambridge. These were examined by Mr. F. W. Putnam, who reported upon them to the Boston Society of Natural History.[1] He states that during the month of December eels were brought into New Bedford "with eggs in various stages of development; where they spawn is not yet known." The specimens examined by Mr. Putnam "had the ovaries in various stages of development. In two the ovaries were very small, and the eggs in them exceedingly minute. From these the series showed a gradual increase in the size of the ovaries and the contained eggs, to the specimen exhibited, in which the eggs were still so small as only to be seen by a lens of considerable magnifying power, and not yet ready to be excluded, though the ovaries themselves were large and full."

During the month of November, 1878, I found several eels in spawn in the Providence market, and at my request, Mr. Mooney brought me two eels, one of which he pronounced to be a female and the other a male. The ovaries of the female were larger and fuller than in any other female I have examined, and the eggs riper. The eggs of this eel, which was about two feet in length judging by the portion secured from the fisherman by Mr.

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[1] Proceedings of the Boston Society of Natural History, 1878, Vol. 19, p. 279.

Mooney, were distinguishable by the naked eye, were well filled with yolk cells, with a clear nucleus, and measured nearly two millimetres (1:90 inch) in diameter. The under side of the eel was tinged with golden-yellow. Mr. Mooney's so-called male was darker, dull silvery beneath. A microscopic examination showed that the thin sexual gland was quite different in histological structure from that of the ovary, and the examination of several undoubted male eels, with active spermatozoa, showed that Mr. Mooney was right in his conjecture that his supposed male was really such.

Fourteen eels were then obtained, from twelve to about sixteen inches in length, and ten of them were examined with a Tolles fifth and Hartnack immersion, No. 10. Several females were examined, and it was found that it was easy with the microscope to determine the sexes, from the different nature of the histological structure of the reproductive glands. The results of our examination are as follows: The males are abundant, and it seems probable that there is an equality in the number of individuals of the sexes. When about a foot in length, namely, when the eels are about a year old, there are no external structural differences, but at this period the males contain sperm cysts, sperm cells and immature (?) spermatozoa.

When the eels are from eighteen inches to two feet in length, in the autumn and early winter, the external sexual characters appear. This is confined to the style of coloration. No external structural characters could be detected, the form of the head, lips, body, fins and even the single genital pore being identical in the two sexes. In color the females are of a rich yellow on the under side, especially the long anal fin; the median line is silvery, but on each side there is a pale yellowish line. In the males the yellowish tint is entirely wanting, except on the long anal fin, the belly is dull silvery, and pigment spots are numerous beneath the head.

It is probable that the females are larger than the males, and when the ovaries are filled with ripe eggs, the body is a little more swollen than in the males.

The testis, as well as the ovary, is in the eel attached by one edge to each side of the intestine, and hangs vertically down in the body cavity. There is no oviduct, but the eggs or spermatic particles, as the case may be, drop directly by dehiscence into the body cavity, and pass out through a funnel-shaped fold of the peritoneum by a single small pore or opening identical in form and situation (just behind the anus) in each sex. There are not two openings, as has been stated by some authors. The testis does not differ in form and appearance from the ovary when the female is not in spawn, at least we could find no differences except that it is rather thinner. Both the right testis and ovary extend, in individuals about seventeen inches long, from about an inch and a quarter behind the vent, to near the diaphragm; extending on the right side to half way between the anterior end of the gall bladder and the diaphragm, while both the left testis and ovary are shorter than the right, ending an inch behind the diaphragm.

Microscopically examined the ovarian eggs lie in rows, with the stroma or tissue of fat cells between them. In the testis the spermatozoa are developed in sperm cysts, or "mother cells," much smaller than the ovarian egg (one-sixth to one-fifth mm). The mother cells contain a nucleus about one-third the diameter of the mother cell; in the nucleus is a dusky nucleolus about one-half the diameter of the nucleus. The sperm-cells are developed in the nucleus. They are nucleated, the nucleus large, and they (the sperm-cells) vary from $\frac{1}{10000}$ to $\frac{1}{3000}$ inch in diameter. The spermatozoa themselves are very minute, from $\frac{1}{50000}$ to $\frac{1}{20000}$ inch in diameter. They are active in their movements, the tail was indistinctly seen, but is present. It is doubtful in my mind whether a male eel when less than eighteen or twenty inches long, *i. e.*, when in its first year, is capable of fertilizing the eggs, as most of the spermatozoa noticed seemed not fully developed. In males twelve to fifteen inches long, *i. e.*, about one year old, the number of spermatozoa was much less than in larger, older individuals.

From information collected from persons living in Providence, it appears that the eels begin to descend the rivers and brooks of Rhode Island and Connecticut at the first frosts, when fishermen begin to catch them in eel-pots. They are in spawn in October, November and December, and probably through the winter, and they probably spawn in shallow salt and brackish water in harbors and at the mouth of estuaries and rivers, where it is well-known eels are speared in winter. That eels spawn in the autumn and early winter, and that the young soon hatch, seems proved by the fact that young eels from two to three inches long appear in the spring, in April and May. I caught an eel at Providence, six inches long in October. It seems probable from this fact and the statements of others,[1] that by the last of summer and early part of autumn the eel hatched in late autumn or the winter attains a length of from six inches to a foot in length, and becomes from sixteen to twenty-four inches long the second year. It is well-known to all who have raised fish, or studied the embryology of animals, that individuals of the same brood may be accelerated or retarded in growth, so that eels a year old may vary greatly in size.[2]

In conclusion, so far as our observations extend, our common American eel descends fresh water streams into the salt water of harbors and estuaries, while those habitually living in the sea spawn at the mouths of rivers and in shallow harbors in the autumn and early winter, if not through the winter; the sexes only differ in color and in the histological structure of the reproductive glands, and do not breed until at least the second year. The eggs and spermatozoa are exceedingly minute, the former must be laid by millions; the young are two or three inches long in the middle or last of the spring, and the eel grows about an inch a month until maturity. It is desirable that these facts and inductions should be proved or disproved, and that the entire history of the breeding habits of the eel, hitherto so obscure, should be cleared up.

Since the preceding lines were written I have read Dr. Syrski's "lecture on the organs of reproduction and the fecundation of fishes and especially of eels" (1874), translated in the Report of the U. S. Commissioner of Fish and Fisheries for 1873–4 and 1874–5. The author gives an interesting review of the various and discordant opinions as to the breeding habits of the European eel. It appears that Carlo Mundini first discovered the ovary of the eel in May, 1777; this was confirmed by Rathke, who described the eggs. Siebold (1863) states that eels may reproduce by parthenogenesis, or are hermaphrodite. In 1872 Ercolani claims to have found spermatozoa in eels, but Syrski is positive that he mistook them for "the molecular movement of the granules found so frequently in the tissues of the animal body." Whether Ercolani was right we have not at present the means of ascertaining, but think it more probable he was right than his critic, Syrski. In the same year (1872), Crivelli and Maggi, of Pavia, claim to have discovered, and have figured the spermatozoa. This memoir we have not yet seen. Syrski does not seem to endorse their statements. In 1874 Prof. Münter stated that he found ovaries in about 3000 eels examined for that purpose, but he never found a male eel, *i. e.*, a milter. He therefore admits that eels are reproduced by parthenogenesis, *i. e.*, from non-fecundated eggs, and remarks, "In all probability the eggs are deposited at the bottom of the Baltic sea from the middle of March to the middle of April, and the young eels, one-half to two inches long, born from such eggs, migrate into fresh water about the beginning of May."

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[1] Last June Mr. D. G. Colwell procured several thousand young eels and placed them in the mill pond. They were about two inches long at that time. Last Saturday, while working in the mill race, he caught one which was over seven inches in length, showing that they had grown about one inch per month since placed in the pond. In about a year from now we may expect good eel fishing in the Shiawassee.—*Quoted from Fenton Independent, Michigan, in Forest and Stream, Nov.*, 1878.

[2] For example, the small eel above referred to, about six inches in length, collected early in October, had not increased in size two months later; it has not been fed since its capture. As regards the food of eels, Mr. S. A. Simmons, Jr., of Providence, informs me that eels sometimes feed on the eggs of the king crab (Limulus), burrowing under the latter when spawning.

Syrski then describes and figures the ovaries and "testes," as he regards them, of the eel. The "eggs" figured as such by him are certainly not such, but are the male sperm-cysts, and he has thus entirely mistaken the sex of the eel. He does not figure or describe the true ovarian egg or the ripe egg, which are, in the American eel at least, wholly different in their mode of development from Syrski's so-called eggs, and so different that we doubt not but that his females were really the males of the European species. He figures and describes a portion of what he regards as a testis, but gives no description of the mother-cells, sperm-cysts and spermatozoa; of the latter he says nothing. It is evident that this observer has been throughout mistaken, and has thrown little light on the subject.

To be sure that I have not been over confident in regard to this matter, after reading Syrski's article I have dissected another living male, and found the mother-cells, sperm-cysts and the exceedingly minute, free-moving spermatozoa, which were more abundant than usual in small males. I also reëxamined the ovary of a female not in spawn, and demonstrated them to Mr. J. S. Kingsley, who adopted the view that the bodies he saw could not have been anything else than spermatozoa. My friend, Prof. John Pierce, an experienced microscopist, several times with me examined the free moving spermatozoa (we saw hundreds in active motion), and agrees with me that the bodies we repeatedly observed from different males could not have been organic particles vibrating through the Brownian motion. We both, without distinctly observing the tails, witnessed effects that must have resulted from a rapidly vibrating appendage or "tail."

NOTE.—Since the above was written I have received (Dec. 12) from Mr. Vinal N. Edwards, of the U. S. Fish Commission, a number of eels from Wood's Holl, Mass., forwarded at the suggestion of Prof. Baird. There were two races or varieties among them, some dark with yellow on the belly, others light and silvery beneath, with the anal fin bright red, as well as the edges of the pectoral fins. I supposed that the yellow bellied ones were females and the silver bellied ones were males, but found males and females of both races; so that while the above remarks concerning the colors of the sexes may apply to what eels I examined from Providence River, in the Wood's Holl specimens, there was absolutely no colorational difference between the sexes, and the difference in color is probably due to the color of the water, and especially the nature of the sea bottom, whether sandy or muddy. The females from Wood's Holl were about ready to spawn, and the males contained more abundant spermatozoa than any others examined, but no milt.

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RECENT LITERATURE.

SARS' MOLLUSCAN FAUNA OF ARCTIC NORWAY.[1]—The connection between the northern faunæ of East America and Europe is so close that monographic work of any kind done for one region, deserves and usually obtains the careful attention of students whose field of research is in the other; and it is daily becoming more necessary as wider observation reveals with greater clearness the intimate relations which the two districts bear to one another. This is especially true of the marine animals, and therefore the appearance of Prof. Sars' important work on the Mollusca of Arctic Norway is an event of no little interest for the American student of northern invertebrates. The well known ability of the author as an observer, an investigator and an artistic delineator of the objects he describes, warrant us in expecting results, in the main, of the highest excellence. Yet candor compels us to admit that these expectations are only partly fulfilled.

The work contains a short introduction followed by a description of each species in zoölogical order, without synonymy or des-

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[1] *Bidrag til kundskaben om Norges arktiske Fauna, I, Mollusca Regionis Arcticæ Norvegiæ.* Af Dr. G. O. SARS, Prof. Zoöl. v. Christiania Univ. Universitets program for förste halvaar 1878. Christiania, 1878. 8vo, pp. 466. Map and fifty-two autographic plates.